Published in final edited form as:

Catheter Cardiovasc Interv. 2015 February 15; 85(3): 393–399. doi:10.1002/ccd.25359.

Temporal Trends of Fluoroscopy time and Contrast Utilization in Coronary Chronic Total Occlusion Revascularization: Insights from a Multicenter United States Registry

Tesfaldet T. Michael, MD, MPH¹, Dimitri Karpaliotis, MD³, Emmanouil S. Brilakis, MD, PhD², Mohammed Alomar, MD², Shuaib M. Abdullah, MD², Ben L. Kirkland, BS³, Katrina L. Mishoe, BS³, Nicholas Lembo, MD³, Anna Kalynych, MD³, Harold Carlson, MD³, Subhash Banerjee, MD², Michael Luna, MD², William Lombardi, MD³, and David E. Kandzari, MD³

¹Oregon University Health & science University, Portland, Oregon

²VA North Texas Healthcare System, Dallas, Texas, USA and University of Texas Southwestern Medical Center, Dallas, Texas, USA

³Piedmont Heart Institute, Atlanta, Georgia, USA

⁴St. Joseph Hospital, Bellingham, Washington

Abstract

Background—The impact of operator experience on fluoroscopy time and contrast utilization during percutaneous coronary intervention (PCI) of coronary chronic total occlusions (CTOs) has received limited study.

Methods—We evaluated temporal trends in fluoroscopy time and contrast utilization among 1,363 consecutive CTO PCIs performed at 3 US institutions between January 2006 and November 2011.

Corresponding author: Emmanouil S. Brilakis, MD, PhD, Dallas VA Medical Center (111A), 4500 South Lancaster Road, Dallas, TX 75216, Tel: (214) 857-1547, Fax: (214) 302-1341, esbrilakis@yahoo.com.

All potential conflicts of interest are as follows:

Dr. Michael: Supported by Cardiovascular Training Grant from the National Institutes of Health Award Number T32HL007360

Dr. Karpaliotis: speaker bureau, Abbott Vascular and Medtronic; consultant, Bridgepoint Medical

Dr Brilakis: Speaker honoraria from Janssen, Sanofi, St Jude Medical, Terumo, Abbott Vascular, Asahi and Boston Scientific; research support from Guerbet; spouse is an employee of Medtronic.

Dr. Alomar: none

Dr. Abdullah: none

Mr. Kirkland: none

Ms. Mishoe: None

Dr. Lembo: speaker bureau: Medtronic; advisory board Abbott Vascular and Medtronic

Dr. Kalynych: none

Dr. Carlson: none

Dr. Banerjee: Speaker honoraria from St. Jude Medical, Medtronic, and Johnson & Johnson, Boehringer, Sanofi, Mdcare Global; research support from Boston Scientific and The Medicines Company

Dr. Luna: none

Dr. Lombardi: consultant for Abbott Vascular, Bridgepoint Medical, Medtronic; speaker honoraria from Abbott Vascular, Medtronic and Terumo; equity, Bridgepoint Medical.

Dr. Kandzari: Research/grant support from Abbott Vascular, Boston Scientific Corporation and Medtronic CardioVascular; Consultant, Boston Scientific Corporation and Medtronic CardioVascular; Institutional educational grant from Bridgepoint Medical/ Boston Scientific Corporation.

Results—Mean age was 65 ± 11 years, 85% of patients were men, 40% had diabetes, 37% had prior coronary artery bypass graft surgery and 42% had prior PCI. The CTO target vessel was the right coronary artery (55%), circumflex (23%), left anterior descending artery (21%), and left main or bypass graft (1%). The retrograde approach was used in 34% of all procedures. The technical and procedural success rates were 85.5% and 84.2%, respectively. The mean procedural time, fluoroscopy time and contrast utilization was 113 ± 61 minutes, 42 ± 29 minutes, and 294 ± 158 ml, respectively. Years since initiation of CTO PCI was independently associated with higher technical success rate (OR=1.52, 95% CI 1.52 to 1.70, $p < 0.001$), lower fluoroscopy time (OR=0.84, 95% confidence intervals (CI) 0.75 to 0.95, $p = 0.005$) and contrast utilization (OR=0.84, 95% CI 0.62 to 0.79, $p < 0.001$) during the study period.

Conclusions—Among selected US-based institutions performing CTO PCI we observed a significant reduction in total fluoroscopy time and contrast utilization paralleled with an improved technical success rate over time.

Keywords

Percutaneous coronary intervention; chronic total occlusion; fluoroscopy; contrast volume; temporal trends

Introduction

Chronic total occlusion (CTO) recanalization remains one of the most challenging percutaneous coronary intervention (PCI) subsets, mainly due to difficulty crossing the lesion with a guidewire (1,2). Complex PCI, including treatment of CTOs (3), has been associated with significant radiation exposure (4–8) and resource utilization, including administration of increased contrast volume (9) that poses risk for radiation-related injury and contrast-induced nephropathy (CIN) (10–14). Accordingly, procedural recommendations and interventions related to radiation and procedure safety have been proposed in patients undergoing PCI (15), including a radiation safety program developed by the Society for Cardiovascular Angiography and Interventions (SCAI) in 2011 (16).

Although operator experience has been correlated with higher CTO PCI success rates (17), whether reductions in radiation exposure and contrast utilization parallel operator experience and procedural outcome has not been evaluated. In the present study we examined the relationship between operator experience, procedural outcome and contrast and fluoroscopy utilization.

Methods

Patient population

Demographic, clinical and procedural data including fluoroscopy time and contrast volume of consecutive patients undergoing CTO PCI between January 2006 and November 2011 at three US centers (St. Joseph Medical Center, Bellingham Washington; Piedmont Heart Institute, Atlanta Georgia; and VA North Texas Healthcare System, Dallas, Texas) was retrospectively analyzed. The study was approved by the institutional review board of each institution.

Definitions

Coronary chronic total occlusions were defined as angiographic evidence of a total occlusion with Thrombolysis In Myocardial Infarction (TIMI) grade 0 or 1 and estimated duration of at least 3 months. Estimation of occlusion duration was based upon first onset of angina, prior history of myocardial infarction in the target vessel territory or comparison with a prior angiogram. Contrast volume use (ml) and fluoroscopy time (min) were recorded for each procedure. Fluoroscopy time and contrast volume higher than 75th percentile were classified as increased.

Technical success was defined as successful CTO recanalization with achievement of <50% residual diameter stenosis within the treated segment and restoration of TIMI grade 3 antegrade flow. Procedural success was defined as achievement of technical success and with no in-hospital major adverse cardiac events (MACE). In-hospital MACE included any of the following adverse events prior to hospital discharge: death from any cause, Q-wave myocardial infarction (MI), recurrent angina requiring urgent repeat target vessel revascularization with PCI or coronary bypass surgery, or tamponade requiring pericardiocentesis or surgery.

Statistical Analysis

Clinical characteristics, angiographic measures and in-hospital outcomes were reported using descriptive statistics. Continuous variables were presented as mean with standard deviation and compared using the t-test or Wilcoxon rank-sum test, as appropriate. Categorical variables were expressed as percentages and compared using the chi-square or the Fisher's exact test, as appropriate. Both fluoroscopy time and contrast volume were converted to binary variables (<75 percentile or >75 percentile). Multiple logistic regression analysis was performed to identify variables independently associated with fluoroscopy time and contrast volume, respectively.

For fluoroscopy time, variables with $p < 0.25$ on univariable analysis (history of MI, PCI, prior CABG and stroke, years since start of CTO PCI registry at each center, CTO target vessel, use of the retrograde approach, procedural success, and major complications) were included in the model. For contrast volume, variables with $p < 0.25$ on univariable analysis (years since start of CTO PCI, use of the retrograde approach, procedural success and gender, as well as history of prior CABG, history of MI and history of PCI), which are known to be associated with more challenging PCI were included in the model. All statistical analyses were performed with JMP version 9.0 (SAS Institute, Cary, North Carolina).

Results

Patient characteristics

During the study period, a total of 1,363 consecutive patients underwent CTO PCI at 3 US institutions: St. Joseph Medical Center, Bellingham, WA (N=728); Piedmont Heart Institute, Atlanta, GA (N=360); and VA North Texas Healthcare System, Dallas, TX (N=275). The baseline demographic, clinical and angiographic characteristics of the study population are

shown in Table 1. Overall, 85% of the patients were men with mean age of 64.5 ± 11 years. Forty percent had diabetes, more than one-third (37%) had prior CABG, 42% experienced prior myocardial infarction and 42% had history of prior PCI. The most common target vessel intervened in more than half of the patients was the right coronary artery (55%), followed by the left circumflex (23%) and left anterior descending arteries (21%).

Procedural Outcomes and Trends

Most procedures (66%) were performed using the antegrade approach; the retrograde approach was used in 34%. The overall technical and procedural success rates were 85.5% and 84.2%, respectively (Table 2). A total of 24 major in-hospital complications occurred (Table 2). A significant increase in the procedural success rate ($p < 0.001$) and use of the retrograde approach ($p < 0.001$) was observed with each additional year since initiation of CTO PCI at each center (Table 3, Figure 1). Table 3 depicts mean fluoroscopy time and contrast utilization for CTO PCI over 6-year period. St. Joseph Medical Center had consecutive 6 year (2006 to 2011) data, while VA North Texas Healthcare System and Piedmont Heart Institute had 4 year (2008–2011) and 2 year (2010–2011) data, respectively.

Fluoroscopy Time

Overall, the mean and median fluoroscopy time was 42 ± 29 and 36 (interquartile range, 21.0 to 52.2) minutes, respectively. The mean and median procedure time was 113 ± 61 and 101 (interquartile range, 68 to 142) minutes, respectively. Procedures with fluoroscopy time above 75th percentile (> 52.2 minutes) were categorized as prolonged fluoroscopy time procedures (Table 2).

In univariable analysis, patients with prolonged fluoroscopy time were more likely to have history of MI, PCI, stroke, prior CABG, right coronary artery target vessel, use of the retrograde approach, higher procedural failure rates and higher rates of in-hospital complications (Table 2). Moreover, having prolonged fluoroscopy time was inversely correlated with years since initiation of CTO PCI registry (Figure 2). In multivariable analysis, prior CABG, right coronary artery target vessel, fewer years since initiation of CTO PCI registry at each center, use of the retrograde approach, and procedural failure were independently associated with prolonged fluoroscopy time (Table 4). Although on invariable analysis the in-hospital complications complication rate was higher among patients with prolonged fluoroscopy time ($p = 0.002$), no independent association was seen on multivariable analysis. Similar to fluoroscopy time, procedure time significantly decreased over time ($p < 0.001$).

Contrast Utilization

The mean and median contrast volume was 294 ± 158 and 265 ml (interquartile range, 180 ml to 380 ml), respectively. Patients who received more than the 75th percentile (> 380 ml) were categorized as receiving high contrast volume (Table 1 and 2). In univariable analysis, increased contrast volume was associated with fewer years since initiation of the CTO PCI program, use of the retrograde approach, and procedural failure (Table 2). In multivariable analysis, fewer years since initiation of CTO PCI, use of the retrograde approach and procedural failure were independent predictors of increased contrast volume (Table 5).

Although prior CABG and right coronary artery target vessel were independently associated with prolonged fluoroscopy time, these two variables were not associated with increased contrast volume.

Discussion

The major finding of our study is that years since initiation of CTO PCI at each center was independently associated with lower fluoroscopy time and contrast utilization and higher procedural success rates. Moreover, we identified use of the retrograde approach and procedural failure as factors associated with higher fluoroscopy and contrast utilization.

Radiation exposure can result in both deterministic (skin injury) and stochastic (such as cancer) complications (16), but is often under-reported. In a meta-analysis of 65 published CTO PCI studies only 11% of the studies reported the occurrence of radiation skin injury, which occurred in 3 of 2,857 patients (0.1%) (20). Similarly, Vargas et al found under-reporting of radiation exposure in contemporary interventional cardiology trials (21). Fluoroscopy time is one of the major determinants of radiation exposure. Compared to non-CTO PCI, CTO PCI has been may be associated with as much as 40% higher radiation exposure (22).

Our study identified several factors associated with prolonged fluoroscopy time, such as prior CABG, right coronary artery CTOs and fewer years since initiation of the CTO PCI registry. Years since CTO PCI registry initiation is a surrogate of the institution's and operator's experience with CTO PCI and also correlated with higher use of the retrograde approach and higher procedural success rates. In other words experienced operators were not only more successful in CTO PCI, but were also more efficient regarding fluoroscopy time and contrast administration, as has been reported in prior studies by Fetterly et al and Tsapaki et al (8,22). The finding that prior CABG was independently associated with increased fluoroscopy time likely reflects the complexity of CTO revascularization in this group of patients (23).

Reducing radiation exposure during CTO PCI is critical for both patients and operators. This can be accomplished in several ways, such as: (1) using 7.5 frame per second fluoroscopy; (2) limiting the use of cine angiography and using the "fluoro-store" function instead; (3) optimizing the position of the table and image intensifier; (4) rotating the image intensifier to distribute radiation exposure to multiple skin entry sites; (5) using shielding; (6) closely monitoring radiation exposure throughout the duration of the procedure and terminating the procedure if a pre-defined threshold (usually 6–8 Gray air kerma exposure) is reached without successful lesion crossing (16).

Contrast-induced nephropathy (CIN), a common complication after PCI, is the third most common cause of acute renal failure in patients admitted to a hospital and is associated with increased morbidity, mortality, and medical costs (10,18,24–27). Administration of higher volume of contrast is associated with higher risk for contrast nephropathy (10–12,14) and CTO PCI has been associated with high contrast volume administration (Table 6) (3,28–32). In a recent weighted meta-analysis of 18,061 patients from 65 Studies by Patel et al the

incidence of contrast nephropathy varied from 2.4% to 18.1%, with a pooled estimate rate of 3.4% (20).

Our study demonstrated that treatment center, time since initiation of CTO PCI registry, retrograde CTO PCI, and CTO PCI failure were independently associated with increased contrast volume. Similar to radiation, limiting the volume of administered contrast is important to minimize contrast-related side effects. This can be accomplished by not performing ad hoc CTO PCI, minimizing the frequency of test injections, and aborting the procedure if CTO crossing has not been achieved before reaching a pre-determined contrast volume limit (18,19). Moreover, the introduction of new dedicated CTO devices for subintimal tracking and re-entry (34) and refinement of the retrograde techniques may have contributed to the improvement of procedural rate and reduction of procedural time, fluoroscopy time and contrast load.

Our study has several limitations. First, the data were analyzed retrospectively and thus are subject to the inherent weaknesses of retrospective studies. Second, air kerma radiation exposure was not systematically documented, and as a result fluoroscopy time was used as a surrogate marker for radiation exposure. Third, no systematic screening for the occurrence of contrast-induced nephropathy was performed, and hence its incidence could not be reliably estimated. Fourth, all procedures were performed at centers that have invested significant resources to develop expertise in treating coronary CTOs and may not be applicable to all centers performing CTO PCI (33).

In summary, among selected US programs performing CTO PCI a significant reduction in total fluoroscopy time and contrast utilization was observed over time in spite of improving technical success rates, suggesting a significant impact of the learning curve on CTO PCI efficiency.

Abbreviations

CABG	Coronary Artery Bypass Graft surgery
CIN	Contrast-Induced Nephropathy
CTO	Chronic Total Occlusion
MACE	Major Adverse Cardiac Events
MI	Myocardial infarction
PCI	Percutaneous Coronary Intervention
TIMI	Thrombolysis In Myocardial Infarction

References

1. Stone GW, Kandzari DE, Mehran R, et al. Percutaneous recanalization of chronically occluded coronary arteries: a consensus document: part I. *Circulation*. 2005; 112:2364–2372. [PubMed: 16216980]

2. Stone GW, Reifart NJ, Moussa I, et al. Percutaneous recanalization of chronically occluded coronary arteries: a consensus document: part II. *Circulation*. 2005; 112:2530–2537. [PubMed: 16230504]
3. Morino Y, Kimura T, Hayashi Y, et al. In-hospital outcomes of contemporary percutaneous coronary intervention in patients with chronic total occlusion insights from the J-CTO Registry (Multicenter CTO Registry in Japan). *JACC Cardiovasc Interv*. 2010; 3:143–151. [PubMed: 20170870]
4. Bernardi G, Padovani R, Morocutti G, et al. Clinical and technical determinants of the complexity of percutaneous transluminal coronary angioplasty procedures: analysis in relation to radiation exposure parameters. *Catheter Cardiovasc Interv*. 2000; 51:1–9. discussion 10. [PubMed: 10973008]
5. Nikolsky E, Pucelikova T, Mehran R, et al. An evaluation of fluoroscopy time and correlation with outcomes after percutaneous coronary intervention. *J Invasive Cardiol*. 2007; 19:208–213. [PubMed: 17476034]
6. Mercuri M, Xie C, Levy M, Valettas N, Natarajan MK. Predictors of increased radiation dose during percutaneous coronary intervention. *Am J Cardiol*. 2009; 104:1241–1244. [PubMed: 19840569]
7. Tsapaki V, Magginas A, Vano E, et al. Factors that influence radiation dose in percutaneous coronary intervention. *J Interv Cardiol*. 2006; 19:237–244. [PubMed: 16724966]
8. Fetterly KA, Lennon RJ, Bell MR, Holmes DR Jr, Rihal CS. Clinical determinants of radiation dose in percutaneous coronary interventional procedures: influence of patient size, procedure complexity, and performing physician. *JACC Cardiovasc Interv*. 2011; 4:336–343. [PubMed: 21435613]
9. Kahn JK, Rutherford BD, McConahay DR, et al. High-dose contrast agent administration during complex coronary angioplasty. *Am Heart J*. 1990; 120:533–536. [PubMed: 2389689]
10. McCullough PA, Wolyn R, Rocher LL, Levin RN, O'Neill WW. Acute renal failure after coronary intervention: incidence, risk factors, and relationship to mortality. *Am J Med*. 1997; 103:368–375. [PubMed: 9375704]
11. Rihal CS, Textor SC, Grill DE, et al. Incidence and prognostic importance of acute renal failure after percutaneous coronary intervention. *Circulation*. 2002; 105:2259–2264. [PubMed: 12010907]
12. Mehran R, Nikolsky E. Contrast-induced nephropathy: definition, epidemiology, and patients at risk. *Kidney Int Suppl*. 2006:S11–S15. [PubMed: 16612394]
13. Gurm HS, Dixon SR, Smith DE, et al. Renal function-based contrast dosing to define safe limits of radiographic contrast media in patients undergoing percutaneous coronary interventions. *J Am Coll Cardiol*. 2011; 58:907–914. [PubMed: 21851878]
14. Weisbord SD, Palevsky PM. Strategies for the prevention of contrast-induced acute kidney injury. *Curr Opin Nephrol Hypertens*. 2010; 19:539–549. [PubMed: 20625289]
15. Levine GN, Bates ER, Blankenship JC, et al. 2011 ACCF/AHA/SCAI Guideline for Percutaneous Coronary Intervention: executive summary: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the Society for Cardiovascular Angiography and Interventions. *Catheter Cardiovasc Interv*. 2012; 79:453–495. [PubMed: 22328235]
16. Chambers CE, Fetterly KA, Holzer R, et al. Radiation safety program for the cardiac catheterization laboratory. *Catheter Cardiovasc Interv*. 2011; 77:546–556. [PubMed: 21254324]
17. Karpaliotis D, Michael TT, Brilakis ES, et al. Retrograde coronary chronic total occlusion revascularization: procedural and in-hospital outcomes from a multicenter registry in the United States. *JACC Cardiovasc Interv*. 2012; 5:1273–1279. [PubMed: 23257376]
18. Mehran R, Aymong ED, Nikolsky E, et al. A simple risk score for prediction of contrast-induced nephropathy after percutaneous coronary intervention: development and initial validation. *J Am Coll Cardiol*. 2004; 44:1393–1399. [PubMed: 15464318]
19. Laskey WK, Jenkins C, Selzer F, et al. Volume-to-creatinine clearance ratio: a pharmacokinetically based risk factor for prediction of early creatinine increase after percutaneous coronary intervention. *J Am Coll Cardiol*. 2007; 50:584–590. [PubMed: 17692741]
20. Patel VG, Brayton KM, Tamayo A, et al. Angiographic success and procedural complications in patients undergoing percutaneous coronary chronic total occlusion interventions: a weighted meta-

- analysis of 18,061 patients from 65 studies. *JACC Cardiovasc Interv.* 2013; 6:128–136. [PubMed: 23352817]
21. Vargas A, Shroff AR, Vidovich MI. Reporting of radiation exposure in contemporary interventional cardiology trials. *Catheter Cardiovasc Interv.* 2012; 80:570–574. [PubMed: 22121060]
 22. Tsapaki V, Kottou S, Vano E, et al. Patient dose values in a dedicated Greek cardiac centre. *Br J Radiol.* 2003; 76:726–730. [PubMed: 14512333]
 23. Michael TT, Karpaliotis D, Brilakis ES, et al. Impact of Prior Coronary Artery Bypass Graft Surgery on Chronic Total Occlusion Revascularization: Insights from a Multicenter US Registry. *Heart.* 2013; 99:1515–1518. [PubMed: 23598543]
 24. Nash K, Hafeez A, Hou S. Hospital-acquired renal insufficiency. *Am J Kidney Dis.* 2002; 39:930–936. [PubMed: 11979336]
 25. Tziakas D, Chalikias G, Stakos D, et al. Development of an easily applicable risk score model for contrast-induced nephropathy prediction after percutaneous coronary intervention: A novel approach tailored to current practice. *Int J Cardiol.* 2013; 163:46–55. [PubMed: 21641061]
 26. Bartholomew BA, Harjai KJ, Dukkipati S, et al. Impact of nephropathy after percutaneous coronary intervention and a method for risk stratification. *Am J Cardiol.* 2004; 93:1515–1519. [PubMed: 15194023]
 27. Gupta R, Gurm HS, Bhatt DL, Chew DP, Ellis SG. Renal failure after percutaneous coronary intervention is associated with high mortality. *Catheter Cardiovasc Interv.* 2005; 64:442–448. [PubMed: 15789398]
 28. Sianos G, Barlis P, Di Mario C, et al. European experience with the retrograde approach for the recanalisation of coronary artery chronic total occlusions. A report on behalf of the euroCTO club. *EuroIntervention.* 2008; 4:84–92. [PubMed: 19112784]
 29. Kimura M, Katoh O, Tsuchikane E, et al. The efficacy of a bilateral approach for treating lesions with chronic total occlusions the CART (controlled antegrade and retrograde subintimal tracking) registry. *JACC Cardiovasc Interv.* 2009; 2:1135–1141. [PubMed: 19926057]
 30. Mehran R, Claessen BE, Godino C, et al. Long-term outcome of percutaneous coronary intervention for chronic total occlusions. *JACC Cardiovasc Interv.* 2011; 4:952–961. [PubMed: 21939934]
 31. Galassi AR, Tomasello SD, Reifart N, et al. In-hospital outcomes of percutaneous coronary intervention in patients with chronic total occlusion: insights from the ERCTO (European Registry of Chronic Total Occlusion) registry. *EuroIntervention.* 2011; 7:472–479. [PubMed: 21764666]
 32. Bufe A, Haltern G, Dinh W, Wolfertz J, Schleiting H, Guelker H. Recanalisation of coronary chronic total occlusions with new techniques including the retrograde approach via collaterals. *Neth Heart J.* 2011; 19:162–167. [PubMed: 22020996]
 33. Karpaliotis D, Lembo N, Brilakis ES, Kandzari DE. Percutaneous Chronic Total Occlusion Revascularization: Program Development, Resource Utilization, and Economic Outcomes. *Interventional Cardiology Clinics.* 2012; 1:391–395.
 34. Whitlow PL, Burke MN, Lombardi WL, et al. Use of a novel crossing and re-entry system in coronary chronic total occlusions that have failed standard crossing techniques: results of the FAST-CTOs (Facilitated Antegrade Steering Technique in Chronic Total Occlusions) trial. *JACC Cardiovasc Interv.* 2012; 5:393–401. [PubMed: 22516395]

Figure 1.
Technical success rate for percutaneous CTO revascularization overtime

Figure 2.
Mean fluoroscopy time (min) and contrast volume (ml) for percutaneous CTO revascularization overtime

Table 1

Baseline patient and angiographic characteristics, classified according fluoroscopy time and contrast volume.

Variable	Overall (n=1363)	Fluorosc y time ≤56.2 min (n=1022)	Fluorosc y time >56.2 min (n=341)	p	Contrast volume ml (n=1027)	Contrast volume >380 ml (n=336)	p
Clinical Characteristics							
Age (years)*	64.5±10.8	64.7±10.4	65.0±9.1	0.652	64.7±10	65.0±9.1	0.652
Men (%)	85.1	84.9	86.7	0.410	84.4	88.3	0.076
Hypertension (%)	89.0	88.7	90.5	0.404	88.7	90.5	0.388
Hyperlipidemia (%)	94.0	93.6	95.1	0.338	93.6	94.8	0.428
Diabetes (%)	40.0	39.4	41.1	0.618	40.3	38.1	0.510
Heart failure (%)	24.0	23.7	23.8	0.973	23.9	23.3	0.827
Ejection fraction < 40% (%)	22.0	22.2	19.9	0.534	22.9	18.6	0.245
History of myocardial infarction (%)	42.0	40.0	48.4	0.015	41.9	42.5	0.882
History of coronary artery bypass graft surgery (%)	37.0	32.5	50.0	<0.001	36.5	38.1	0.559
History of stroke (%)	6.0	5.0	8.4	0.037	5.7	6.4	0.692
Prior percutaneous coronary intervention (%)	42.0	38.9	48.3	0.003	41.6	41.5	0.964
Angiographic characteristics							
CTO target vessel				<0.001			0.501
Right coronary artery (%)	55	50.3	68.2		54.2	57.7	
Circumflex (%)	23	24.9	16.4		23.7	19.7	
Left anterior descending artery (%)	21	23.9	14.0		21.2	20.6	
Left main/bypass graft (%)	1.0	0.8	1.2		0.9	1.1	
Prior failed attempt for CTO PCI (%)	15	15.4	15.7	0.894	15.3	15.5	0.959

Variable	Overall (n=1363)	Fluoroscop y time ≤6.2 min (n=1022)	Fluorosc py time >6.2 min (n=341)	p	Contrast volume ml (n=1027)	Contrast volume >380 ml (n=336)	p
Retrograde use (%)	34.0	23.7	65.5	<0.001	29.5	48.6	<0.001

* mean ±standard deviation;
CTO, chronic total occlusion; PCI, percutaneous coronary intervention; NA, not applicable;

Table 2

Procedural Outcomes, classified according fluoroscopy time and contrast volume.

Variable	Overall (n=1363)	Fluorosc y time 56.2 min (n=1022)	Fluorosc py time >56.2 min (n=341)	p	Contrast volume 380 ml (n=1027)	Contrast volume >380 ml (n=336)	p
Technical success (%)	85.5	88.7	76.0	<0.001	88.7	75.0	<0.001
Procedural success (%)	84.2	87.8	73.8	<0.001	87.7	73.2	<0.001
Major complications (%)	1.8	1.1	3.7	0.002	1.4	2.8	0.099
Total procedure time (min) *	113±61	88±39	184±59	<0.001	88±38	184±59	<0.001
Total fluoroscopy time (min) *	42±29	NA	NA		29±14	82±27	<0.001
Total air kerma radiation exposure (Gray) *	4.7±3.8	3.7±3.5	8.0±3.0	<0.001	3.7±3.4	8.0±3.0	<0.001
Total contrast volume (ml) *	294±158	247±119	434±177	<0.001	NA	NA	

* mean ±standard deviation;

NA, not applicable; mean, range; NR, not reported

Table 3

Mean fluoroscopy time and contrast utilization for percutaneous intervention of chronic total occlusions over 6-year period

Year*	Fluoroscopy (minute)**	Contrast volume (ml)**	Antegrade PCI (n, %)	Retrograde PCI (n, %)	Total CTO PCI (n, %)	Technical Success Rate
Year 1	55±39	338±190	223 (73.1%)	82 (26.9%)	305 (22.4%)	78.4%
Year 2	42±27	291±137	296 (74.7%)	100 (25.2%)	396 (29.5)	85.5%
Year 3	39±23	293±148	137 (66.8%)	68 (33.2%)	205 (15%)	79.0%
Year 4	39±25	277±142	110 (56.7%)	84 (43.3%)	194 (14.2)	88.1%
Year 5	32±22	223±118	71 (51.5%)	67 (48.5%)	138 (10.1)	97.1%
Year 6	29±17	198±86	64 (51.2%)	61 (48.8%)	125 (9.2)	96.8%
Year 1–6	42±29	294±158	901 (66%)	462 (34%)	1363	85.5%

* Since initiation of CTO PCI registry.

** mean ±standard deviation;

CTO, chronic total occlusion; PCI, percutaneous coronary intervention

Table 4

Logistic regression analysis of the association between various clinical and procedural characteristics and prolonged fluoroscopy time.

Variable	OR	95% CI	p
Years since CTO PCI registry initiation at each center (per 1 year increase)	0.84	0.75, 0.95	0.005
History of myocardial infarction	1.31	0.97, 1.78	0.070
History of percutaneous coronary intervention	1.09	0.78, 1.52	0.58
History of coronary artery bypass graft surgery	2.24	1.64, 3.06	<0.001
History of stroke	1.37	0.75, 152	0.298
CTO Target vessel - RCA (vs. CIRC)	1.99	1.37, 2.92	<0.001
CTO Target vessel - RCA (vs. LAD)	2.42	1.59, 2.02	<0.001
Retrograde approach use	7.7	5.43, 11.07	<0.001
Procedural failure	1.93	1.31, 2.84	0.001
Major complication	2.29	0.81, 6.43	0.116

CTO, chronic total occlusion; PCI, percutaneous coronary intervention; RCA, right coronary artery; LAD, left anterior descending artery; CIRC, left circumflex artery

Table 5

Logistic regression analysis of the association between various clinical and procedural characteristics and increased contrast volume.

Variable	OR	95% CI	p
Years since CTO PCI registry initiation at each center (per 1 year increase)	0.71	0.62, 0.79	<0.001
Male gender	1.54	0.97, 2.49	0.063
History of myocardial infarction	0.98	0.73, 1.33	0.925
History of percutaneous coronary intervention	0.95	0.69, 1.32	0.791
History of coronary artery bypass graft surgery	1.24	0.905, 1.69	0.179
Retrograde approach use	3.36	2.42, 4.69	<0.001
Procedural failure	1.97	1.37, 2.80	<0.001

CTO, chronic total occlusion; PCI, percutaneous coronary intervention

Table 6

Summary of large contemporary CTO PCI registry publications with reports on fluoroscopy time and contrast volume, including > 170 Patients

Author	Year	N (CTO lesions)	Prior CABG, (%)	Overall, retrograde (%)	Technical Success (%)	Major complications (%)	Procedure time, min	Fluoroscopy time, min	Contrast use, ml
Sianos(28)	2008	175	10.9	100	83.4	4.6	NR	59±29	421±167
Kimura(29)	2009	224	17.6	100**	92.4	1.8	173±75	73±42	457±199
Morino(3)	2010	528	9.6	26	86.6	NR	NR	45 (1–301)§	293 (53–1,097)§
Mehran(30)	2011	1791	15.9	NR	68.0	NR	NR	NR	448±229
Galassi(31)	2011	1983	14.6	14	82.9	1.8	NR	42.3±47.4	313±184
Bufe(32)	2011	338	12.8	18.5	81.1	1.5	135±39.7	58.2±18.4	418±160
Present study	2013	1363	37.0	34	85.5	1.8	113±61	42±29	294 ±158

* CART, Controlled antegrade and retrograde subintimal tracking;

§ mean, range; NR, not reported